Wind Technology: New Developments and Markets

Powering Puerto Rico's Future
October 30-13, 2000

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National Renewable Energy Laboratory

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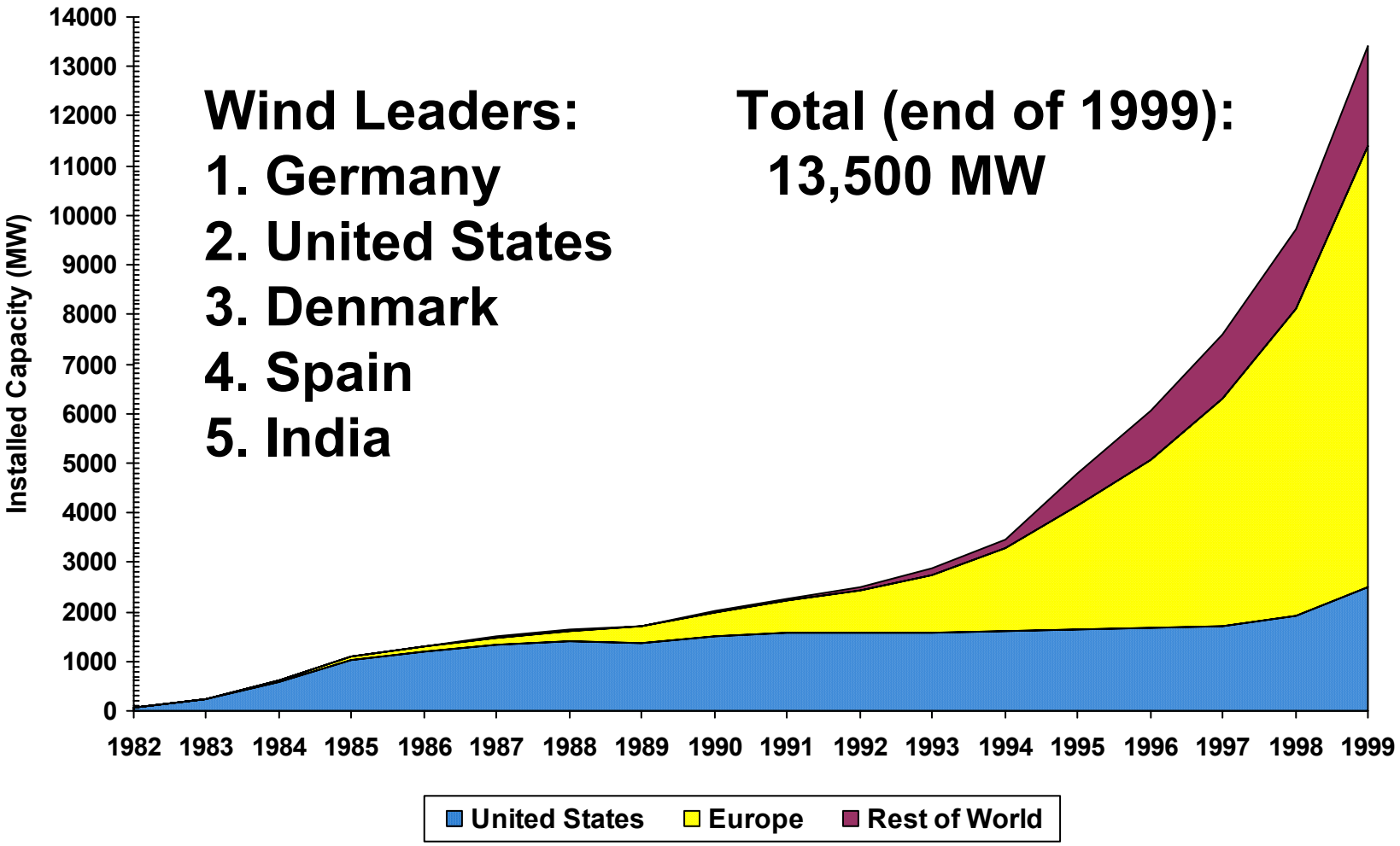
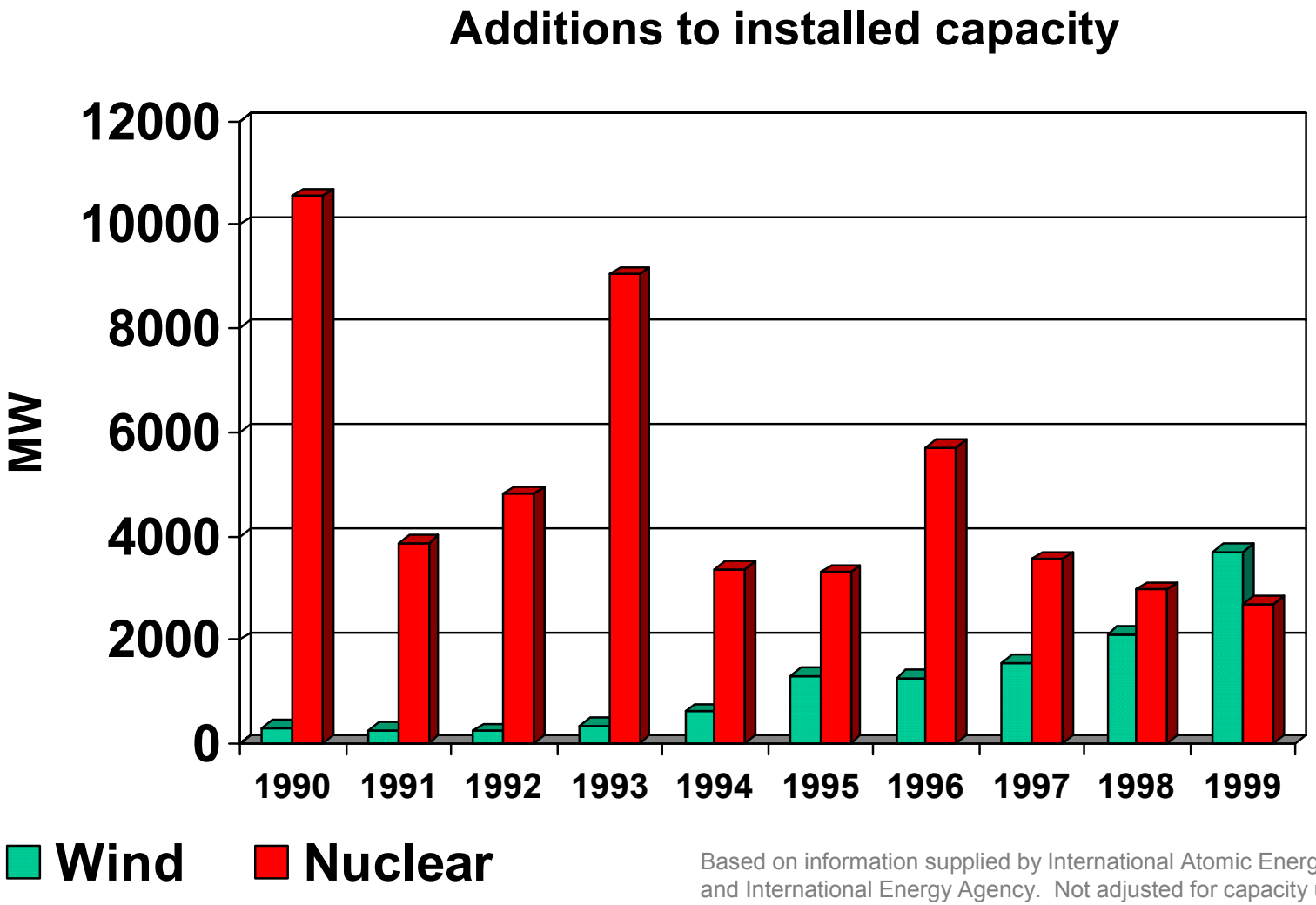
Taking Off Worldwide



Based on information supplied by International Energy Agency.

1999 – More Wind Than Nuclear



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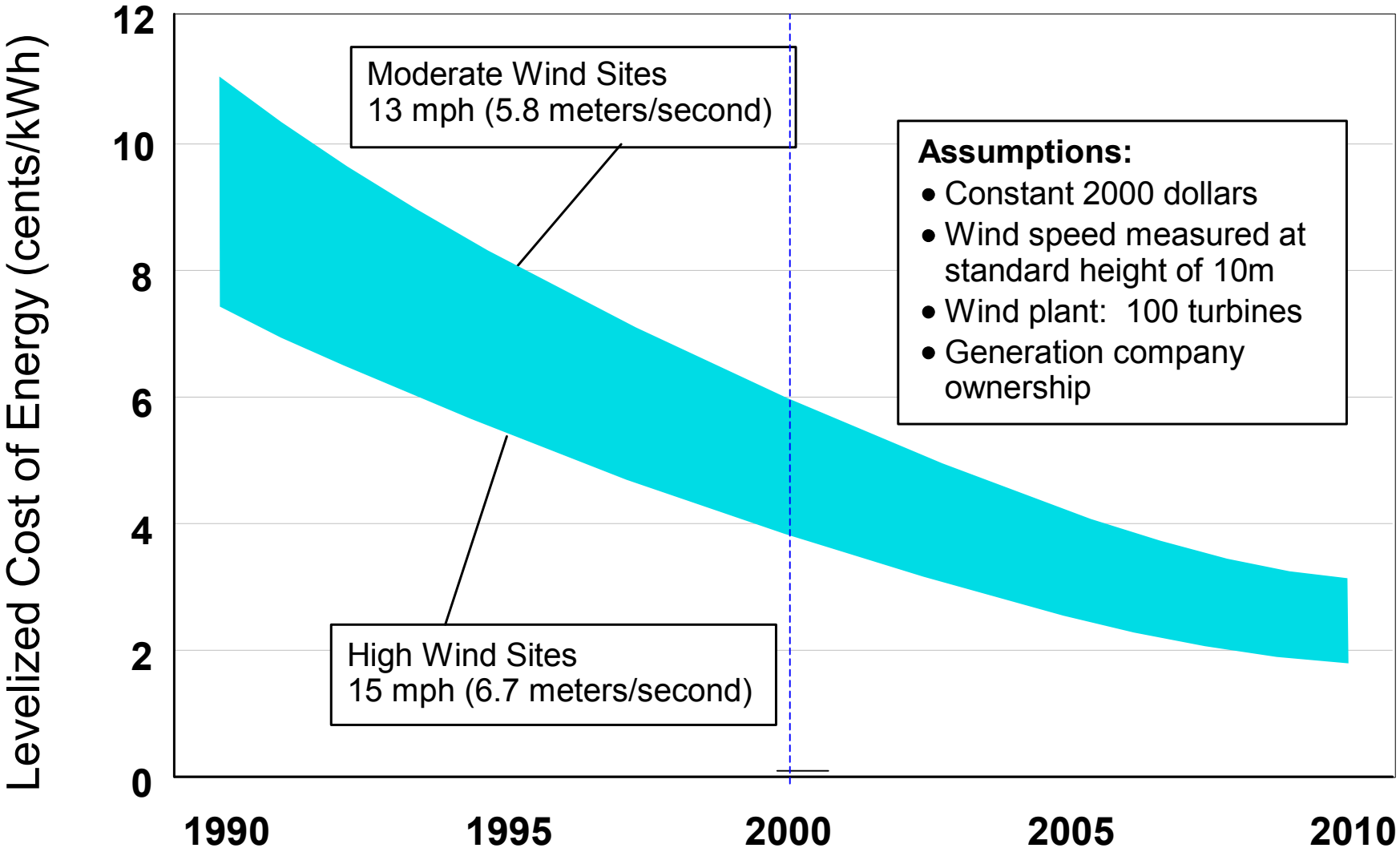
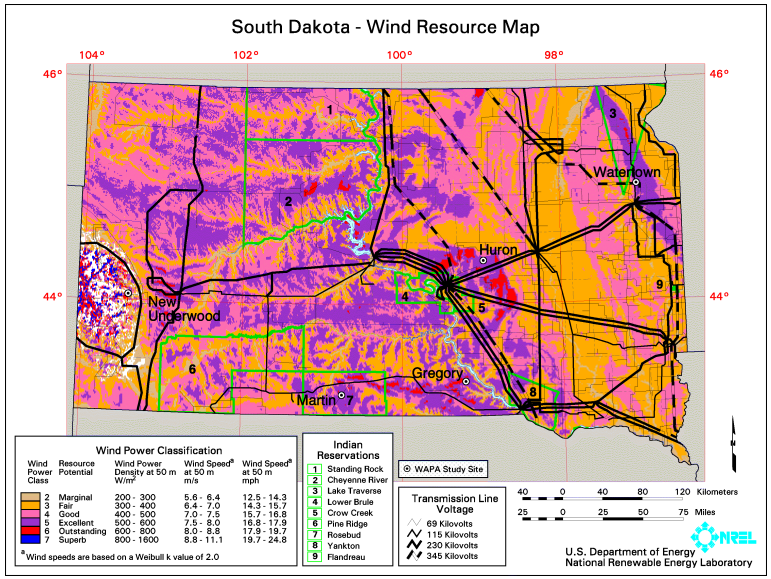
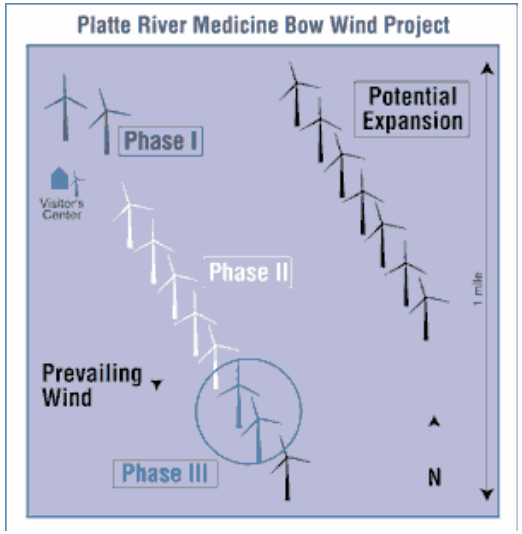

Levelized Cost of Energy (cents/kWh)
12
10
8
6
4
2
0
1990
1995
2000
2005
2010
Moderate Wind Sites
13 mph (5.8 meters/second)
High Wind Sites
15 mph (6.7 meters/second)
Assumptions:
• Constant 2000 dollars
• Wind speed measured at standard height of 10m
• Wind plant: 100 turbines
• Generation company ownership

But… *It really depends*

Location, Location, Location

- Resource
  - 1 mph in average speed is ~ 0.5 cents/kWh
  - Raising tower from 50 to 100m increases kWh ~15% or more in class 4-5
  - Coincidence of wind with load increases value
- Permitting
  - private vs. public land
  - state and local regulations
- Existing site expansion
  - quick, low cost option
- What is included
  - transmission, land





Finances and Incentives

- Production Tax Credit
  - 1.7 cents/kWh (escalating) for 10 years equates to around 1.1 cents/kWh reduction in contract price
  - deadline pressure *increases* costs
- State and Local tax, etc. can be significant

  +/- 0.5 cents/kWh impact

- Public Power (100% debt at tax free rates)

  60% of GenCo or IPP cents/kWh
- Renewable Energy Production Incentive

  annual appropriations problem leads to little impact

Plant and Turbine Size

- Spread “nearly fixed” costs: permitting, crane, legal and other soft costs
- Volume discount from manufacturer
- Economies of scale may bring O&M to under 0.2 cents/kWh
- Next generation of 1.2-2.0 MW machines are 10-15% cheaper/kW

Wind Energy Value

- Emissions free power beginning to have additional value
  - green markets
  - emissions credits
- Reliability/capacity value
- Fuel/Resource diversity and risk

- Intermittency
  - non-dispatchable (different types of kWh)
  - ancillary service costs ??

Cost Conclusions

- The wind industry is delivering ~ 3 cent/kWh contracts, including PTC for large projects
- This price will likely be higher for small projects in new locations
- Value side important: but cost dominates in domestic markets today

Why is Wind different ?

- Intermittent
  - firm/non-firm rates (low capacity factor)
  - scheduling penalties
  - reliability contribution
  - ancillary services

- Remote (& location specific)
  - little excess capacity
  - constrained flow to major load centers

- New
  - not part of established processes
  - expansion and upgrades have been few due to uncertain cost recovery and NIMBY

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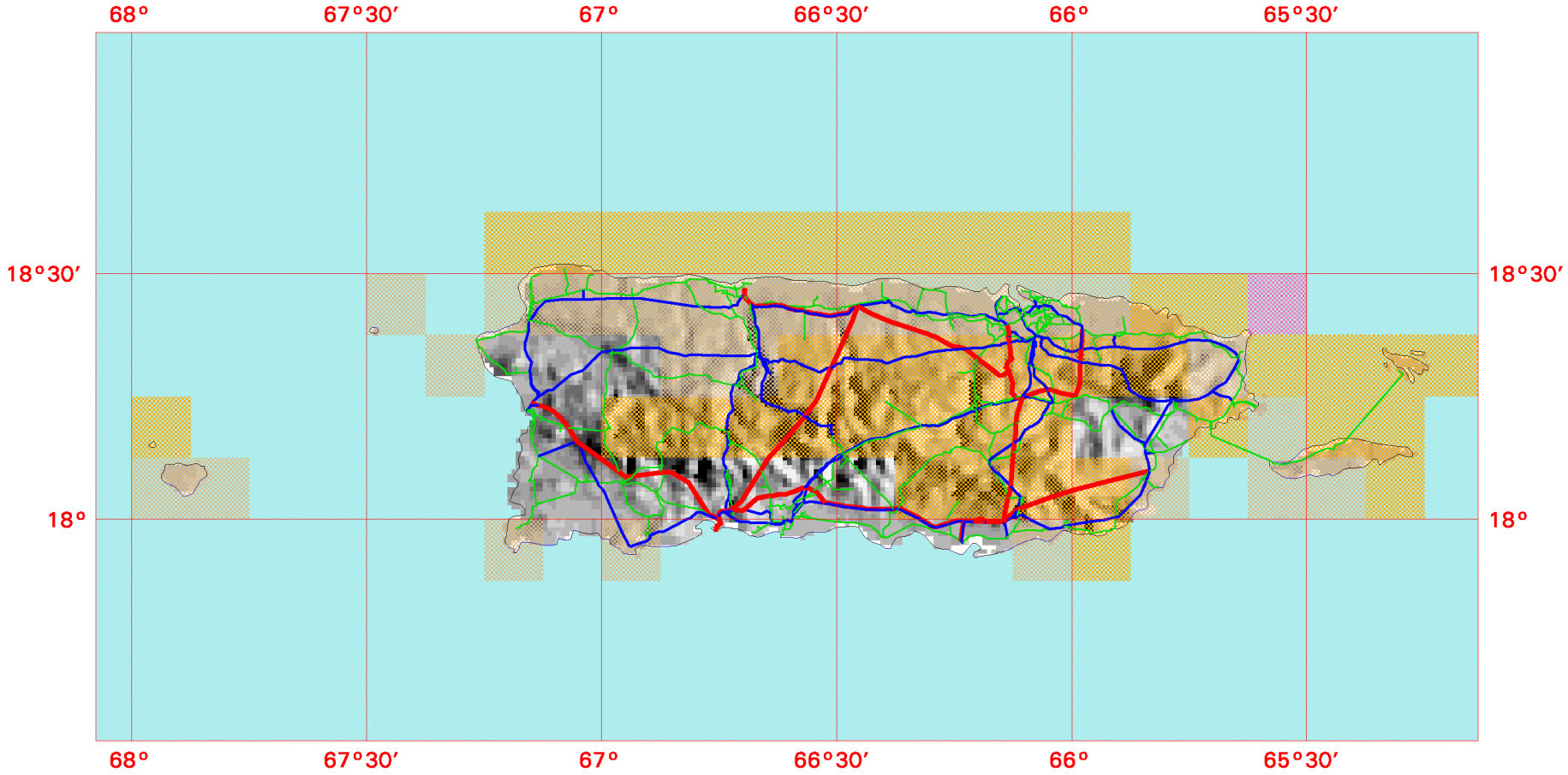
Technology Status

- Technology has matured over 25 years of learning experiences
- Availabilities reported of 98-99%
- Certification to international standards helps to avoid “show stoppers”
- Performance and cost have dramatically improved
  - hardware issues are being promptly addressed
- New hardware is being developed on multiple fronts:
  - higher productivity and lower costs
  - larger sized for both land and off-shore installations
  - tailored designs for high capacity factor, low wind speed and extreme weather conditions

Market Status

- Currently 2,500 MW installed, expect nearly 4,500 MW by the end of 2001
- Most current successful markets take advantage of Federal and State incentives, as well as customer preference for green energy
- Policies will continue to have a major influence on markets until wind energy costs drop
- The Wind Powering America program is stimulating further market interest, and participation of Federal loads
- Future markets will include both large wind farms and smaller, distributed installations

Puerto Rico - Wind Resource Map



Wind Power Classification

Wind Power Class	Resource Potential	Wind Power Density at 50 m W/m^2	Wind Speed[a] at 50 m m/s	Wind Speed[a] at 50 m mph
2	Marginal	200 - 300	5.6 - 6.4	12.5 - 14.3
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4	Good	400 - 500	7.0 - 7.5	15.7 - 16.8
5	Excellent	500 - 600	7.5 - 8.0	16.8 - 17.9
6	Outstanding	600 - 800	8.0 - 8.8	17.9 - 19.7
7	Superb	800 - 1600	8.8 - 11.1	19.7 - 24.8

[a] Wind speeds are based on a Weibull k value of 2.0

Transmission Line Voltage
- 230 Kilovolts
- 115 Kilovolts
- 38 Kilovolts

20 0 20 40 60 80 Kilometers

15 0 15 30 45 Miles

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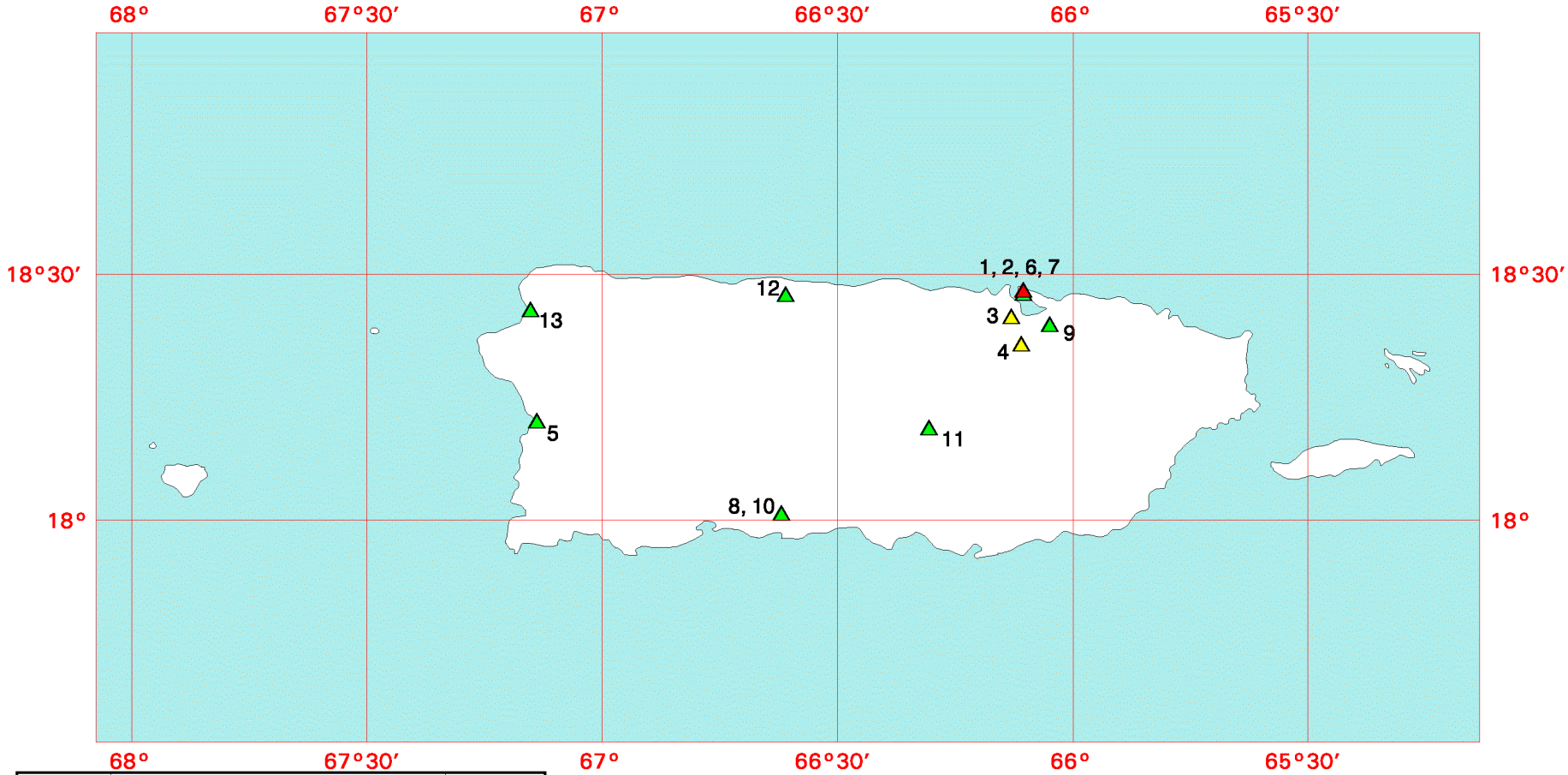
Puerto Rico - Federal Facilities



Agency	Facility	Elec. Use MWh/yr
1 VA	San Juan VA Medical Center	21,228
2 USDA	Federico Degetau Federal Bldg	7,693
3 DED	Fort Buchanan School	2,350
4 GSA	Guaynabo US Post Office & Courthouse	2,008
5 USDA	Tropical Agricultural Research	1,247
6 NPS	San Juan Natl Historic Site	752
7 HHS	San Juan District Laboratory	676
8 USPS	Ponce Main Post Office	570
9 FS	Agricultural Inspection Station	496
10 USPS	Atocha Station	494
11 DOL	Ramey Job Corps Center	-
12 DOL	Barranquitas Job Corps Center	-
13 DOL	Arecivo Job Corps Center	-

Electricity Usage of Federal Facilities
MWh/yr

- 10,000 - 22,000
- 5,000 - 10,000
- 2,000 - 5,000
- 0 - 2,000

20 0 20 40 60 80 Kilometers

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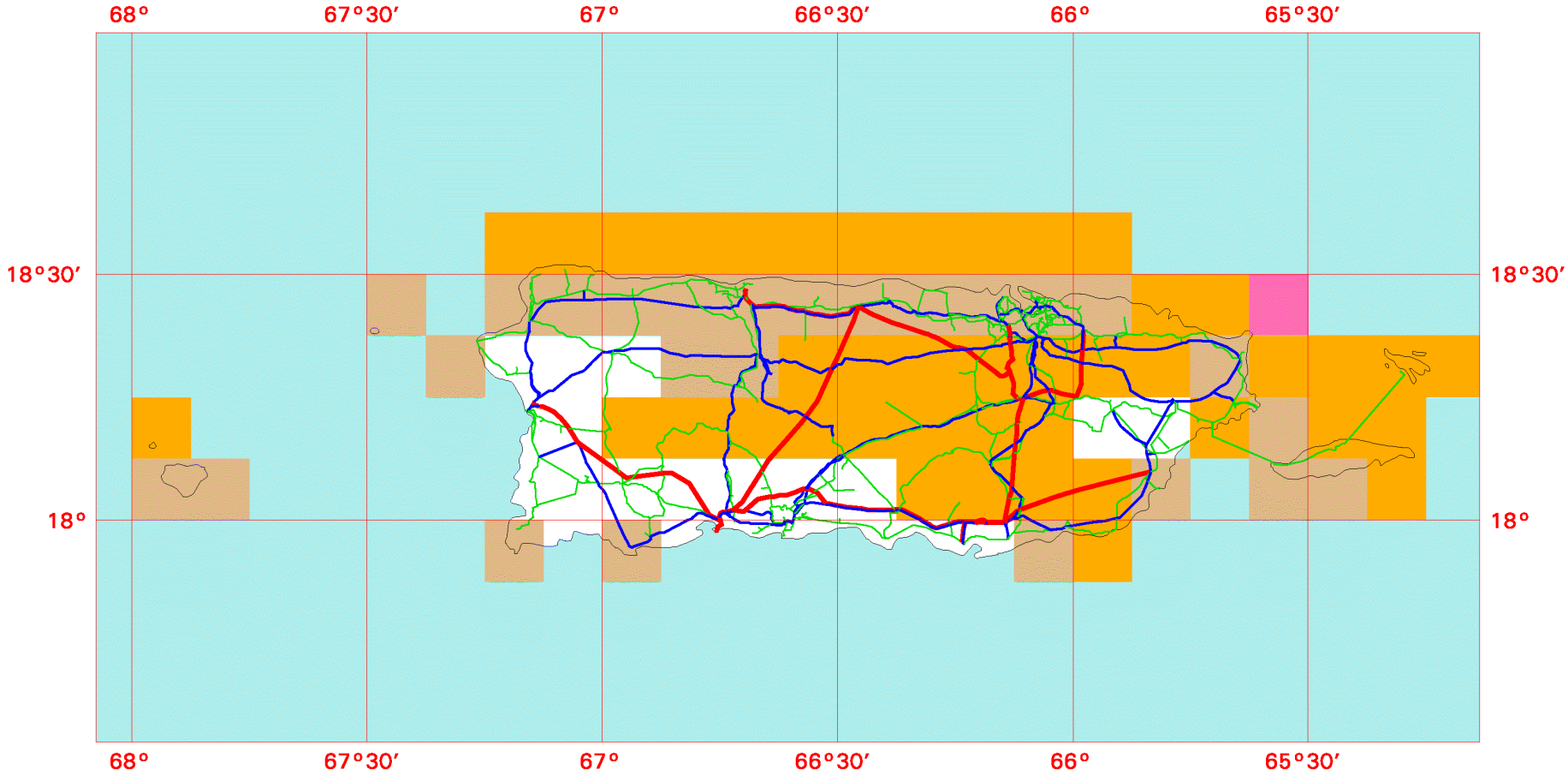
Puerto Rico - Wind Resource Map



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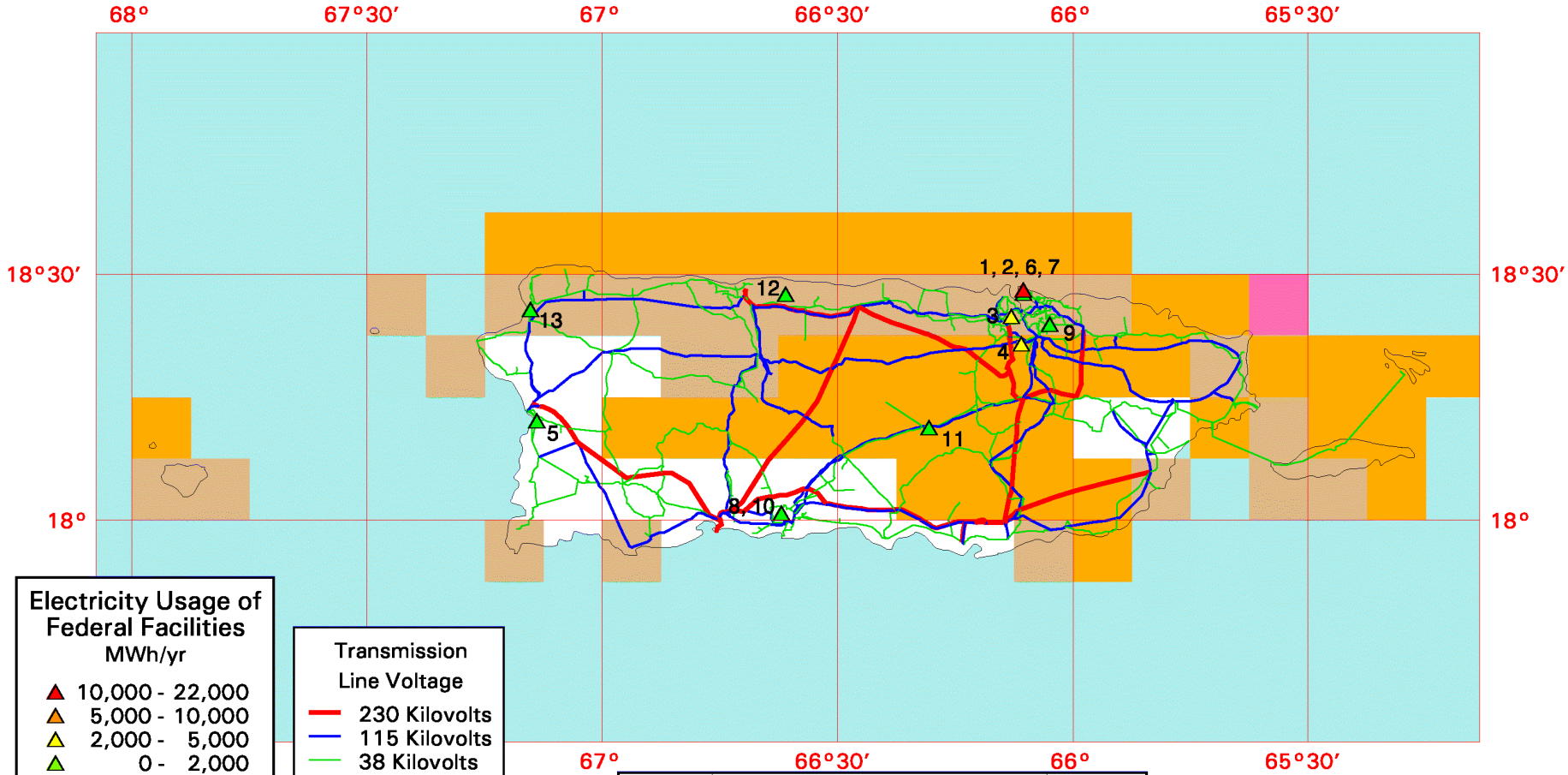

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- 5,000 - 10,000
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20 0 20 40 Kilometers

15 0 15 Miles

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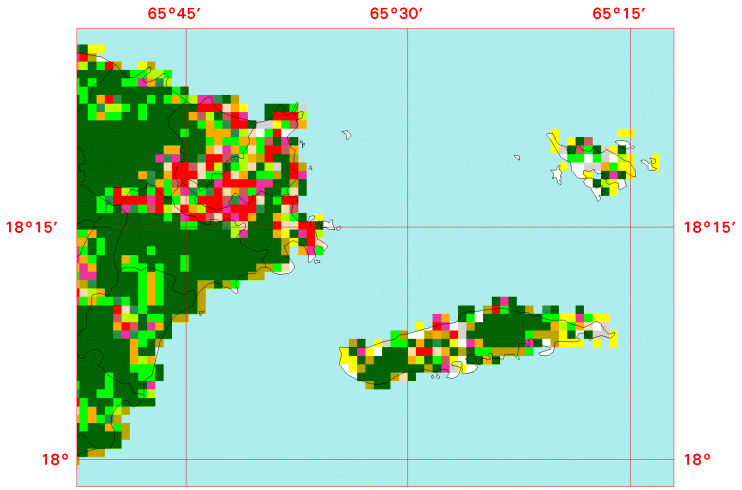
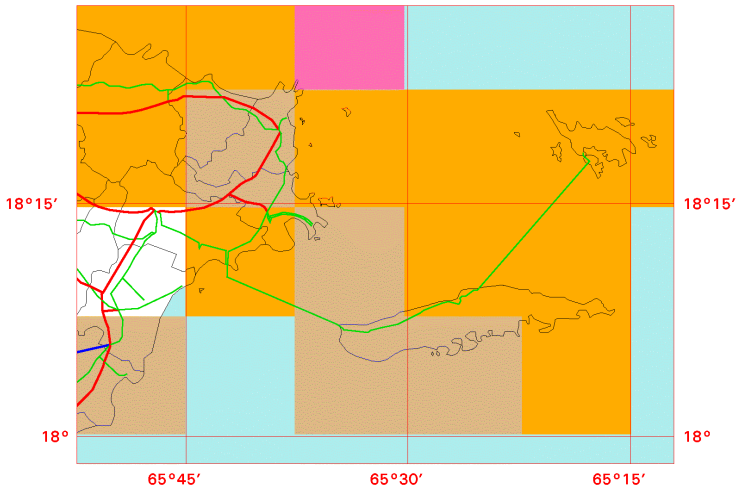
Puerto Rico - Land Use, Wind Resource and Transmission Lines





Land Use

- Urban and Built Up
- Cropland and Pasture
- Cropland/Grassland Mosaic
- Cropland/Woodland Mosaic
- Grassland
- Shrubland
- Mixed Shurbland/Grassland
- Savanna
- Deciduous Forest
- Evergreen Forest
- Mixed Forest
- Herbaceous Wetland
- Barren or Sparsely Vegetated
- No Data

Transmission Line Voltage

- 38 Kilovolts
- 115 Kilovolts
- 230 Kilovolts

N

10 0 10 20 Kilometers

5 0 5 10 15 Miles

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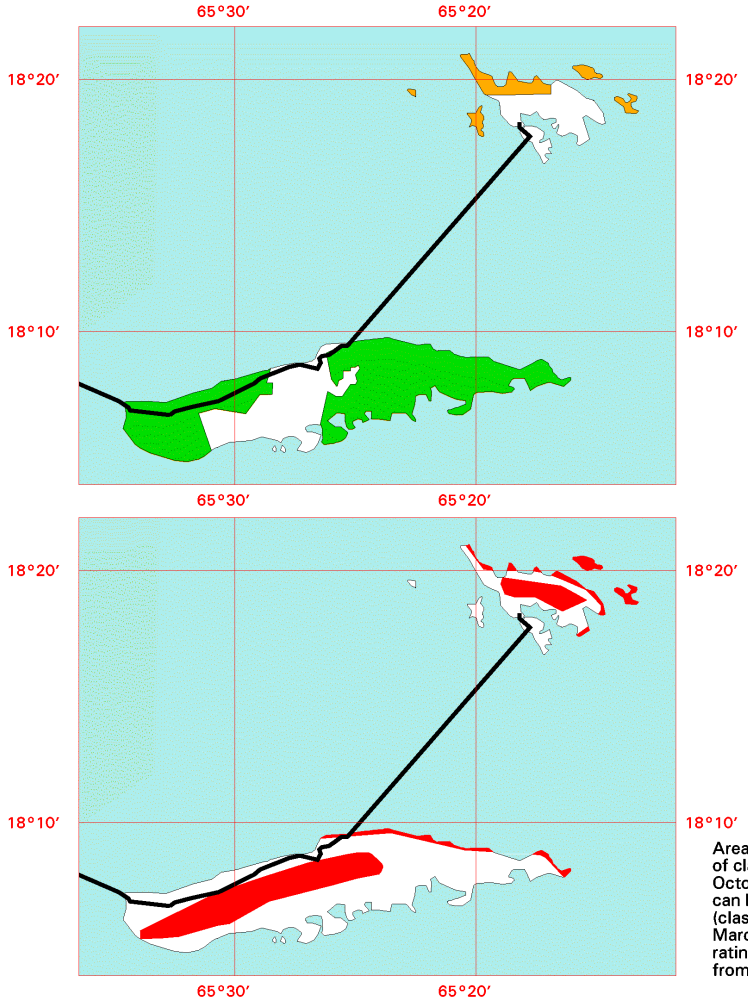
Puerto Rico - Culebra and Vieques Islands
Federal Land Ownership, Wind Resource and Transmission Lines



Federal Land Ownership
- National Park Service
- Navy

Transmission Line Voltage
- 38 Kilovolts

Wind Resource
- Class 3-4
- Class 1-2

Areas with an annual average resource of class 3-4 are useful all year except October. The maximum power rating can be expected from June to August (class 4-6) and from December to March (class 4-5); the minimum power rating (class 2-3) can be expected from Septemper to November.

N

5 0 5 10 15 20 Kilometers

5 0 5 10 Miles

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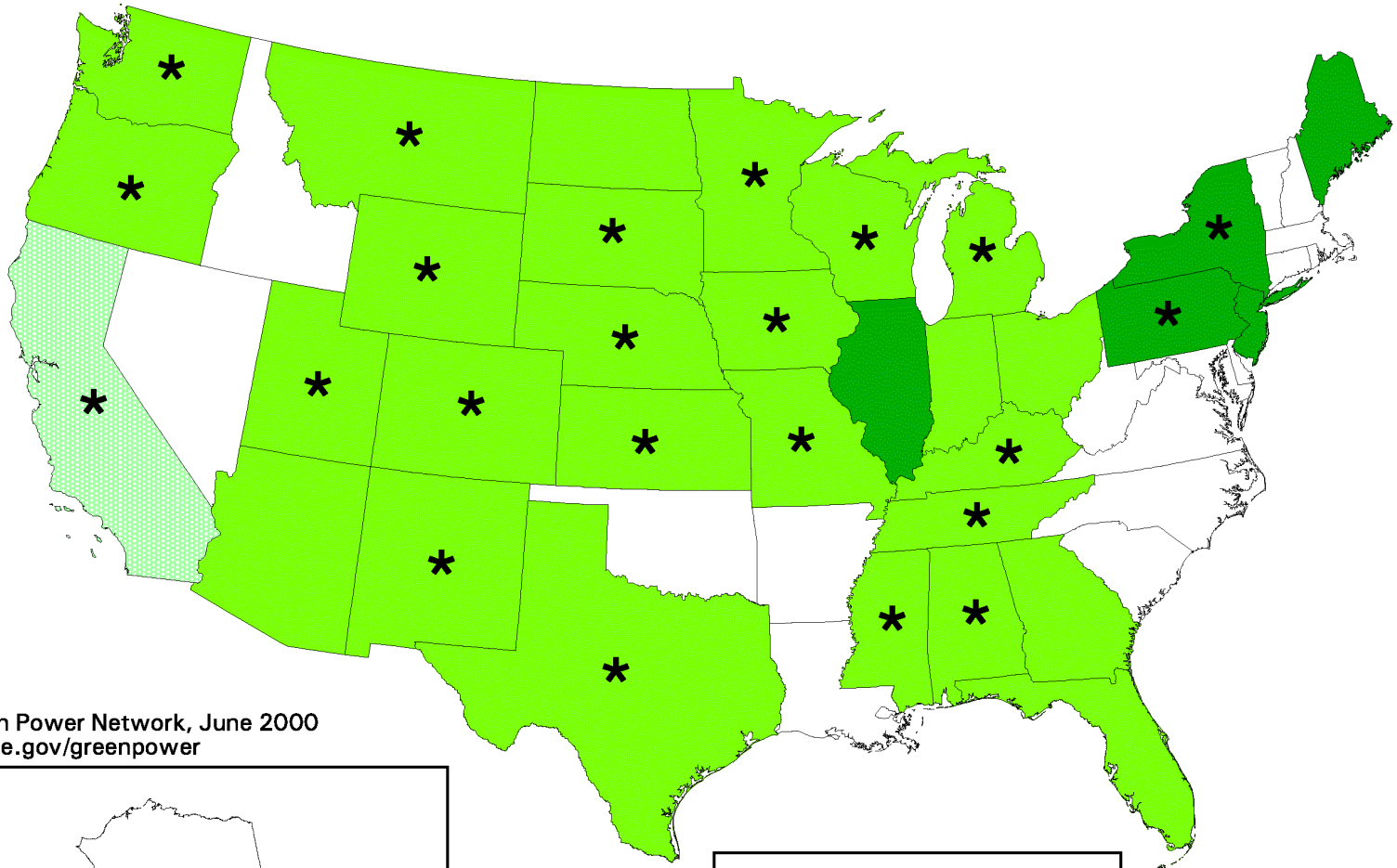
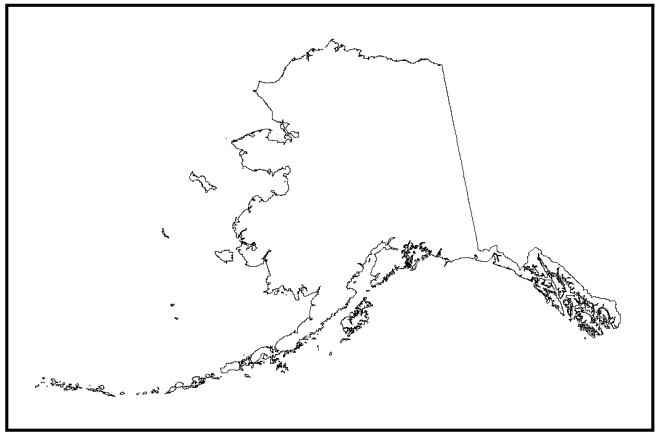
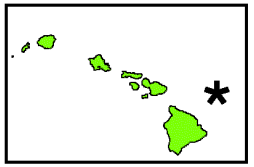
United States - Green Pricing and Green Power



Source: Green Power Network, June 2000
www.eren.doe.gov/greenpower





Legend

- Green Pricing - Utility green pricing programs exist or are being developed
- Green Market - Retail and/or wholesale green power products available
- Green Pricing & Green Market
- * Wind Included

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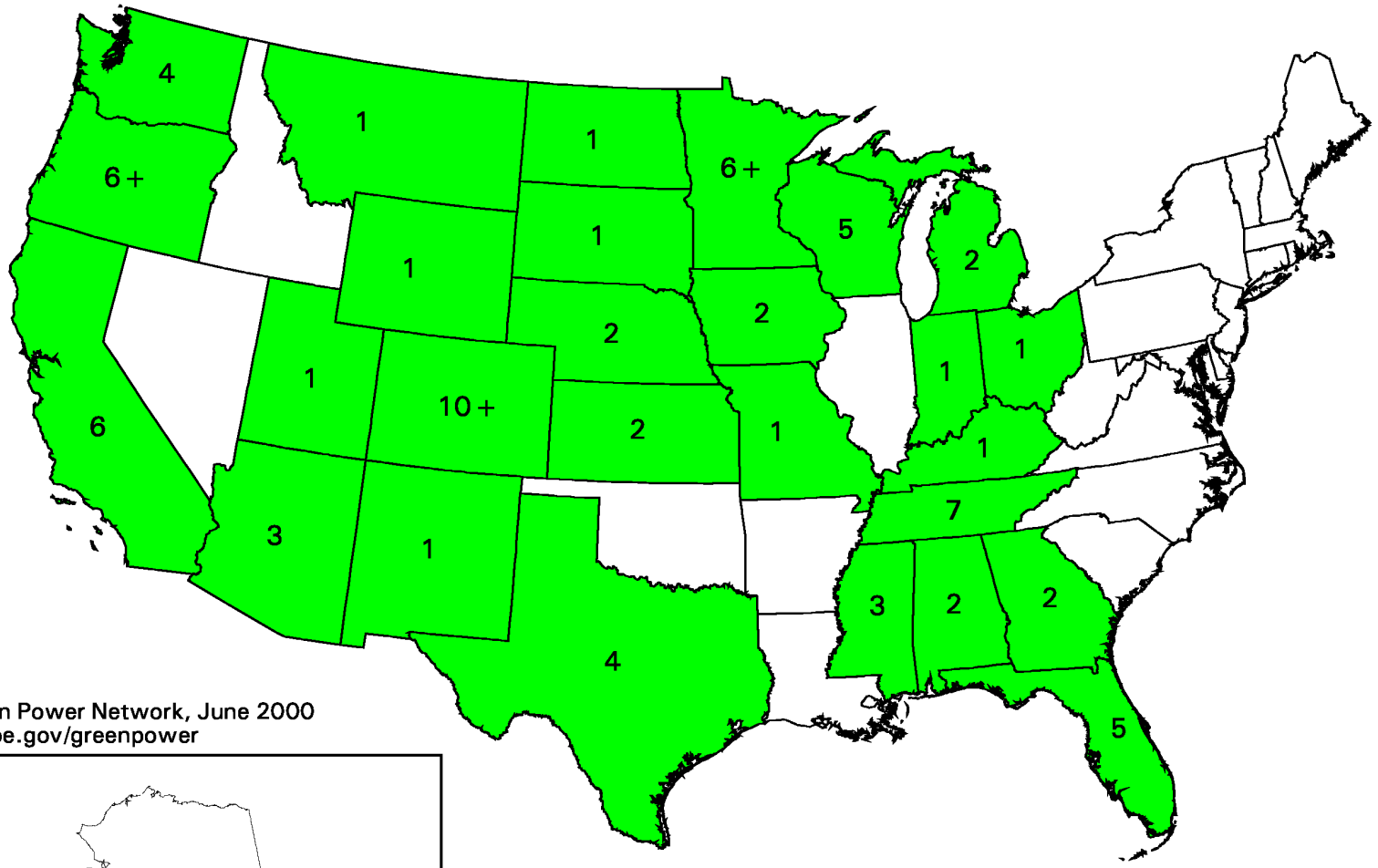
United States - Utility Green Pricing Activities



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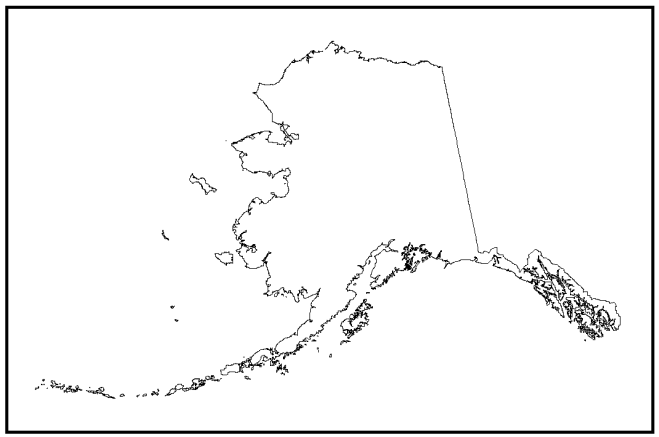

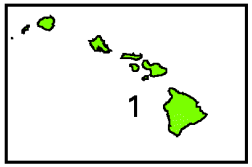

Legend

Utility green pricing programs exist or are being developed

1 Number of utilities offering programs

"+" signifies multiple distribution cooperatives served by the same G&T cooperative.

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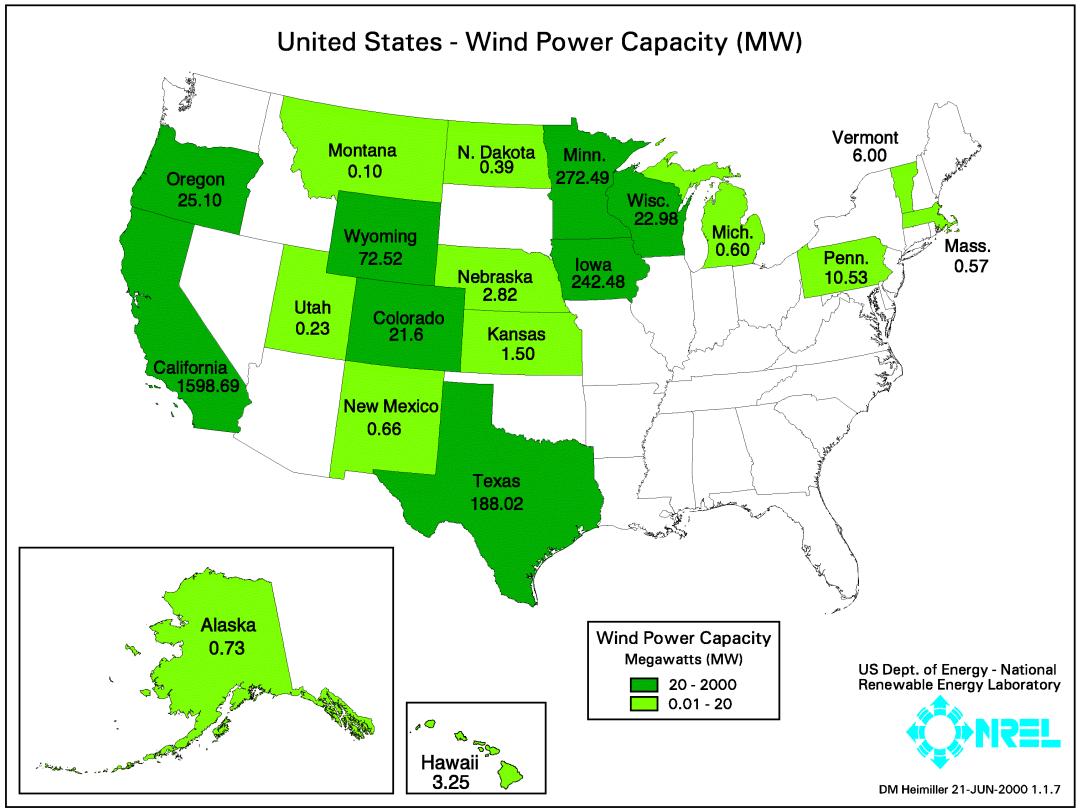
Wind Powering America
FY01 Opportunities

- Federal load aggregation
- Air Quality/SEP
- Green tags
- Native Americans
- State initiatives
- Innovative pilots
- Partnerships
- Regional initiatives



Green Tags - Benefits

To Customer

- Lower cost option
- Opportunity to buy green power if regulated market and no green pricing program offered by utility provider
- Able to aggregate facilities across utility service territories/states/country
- Option for leased facilities that don't pay utility bill
- Requires less staff time

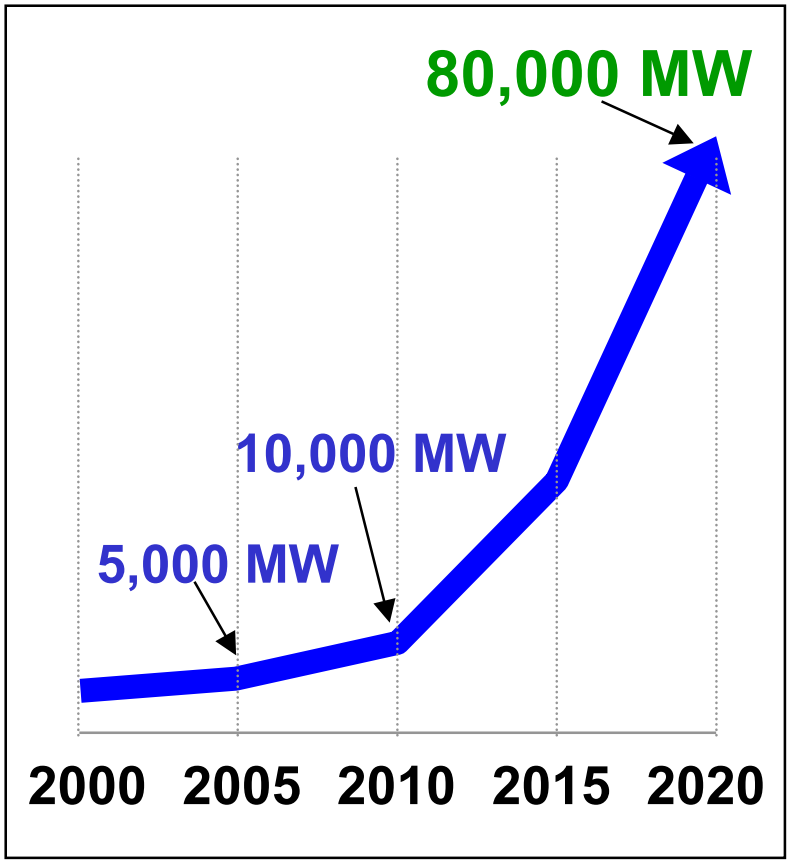
To Supplier

- Contract with green power retail energy supplier not required for renewable developer
  - Simply sell electrons into grid as generic electricity
  - Transmission contract from renewable site to end-use customer not required
- Increased siting flexibility

Federal Goals

Government Facilities

- DOE - 3% RE by 2005; 7 1/2% by 2010
- WPA Federal aggregation- 100 MW by 2001
- FedREWG - 2 1/2% RE by 2005 (pending)



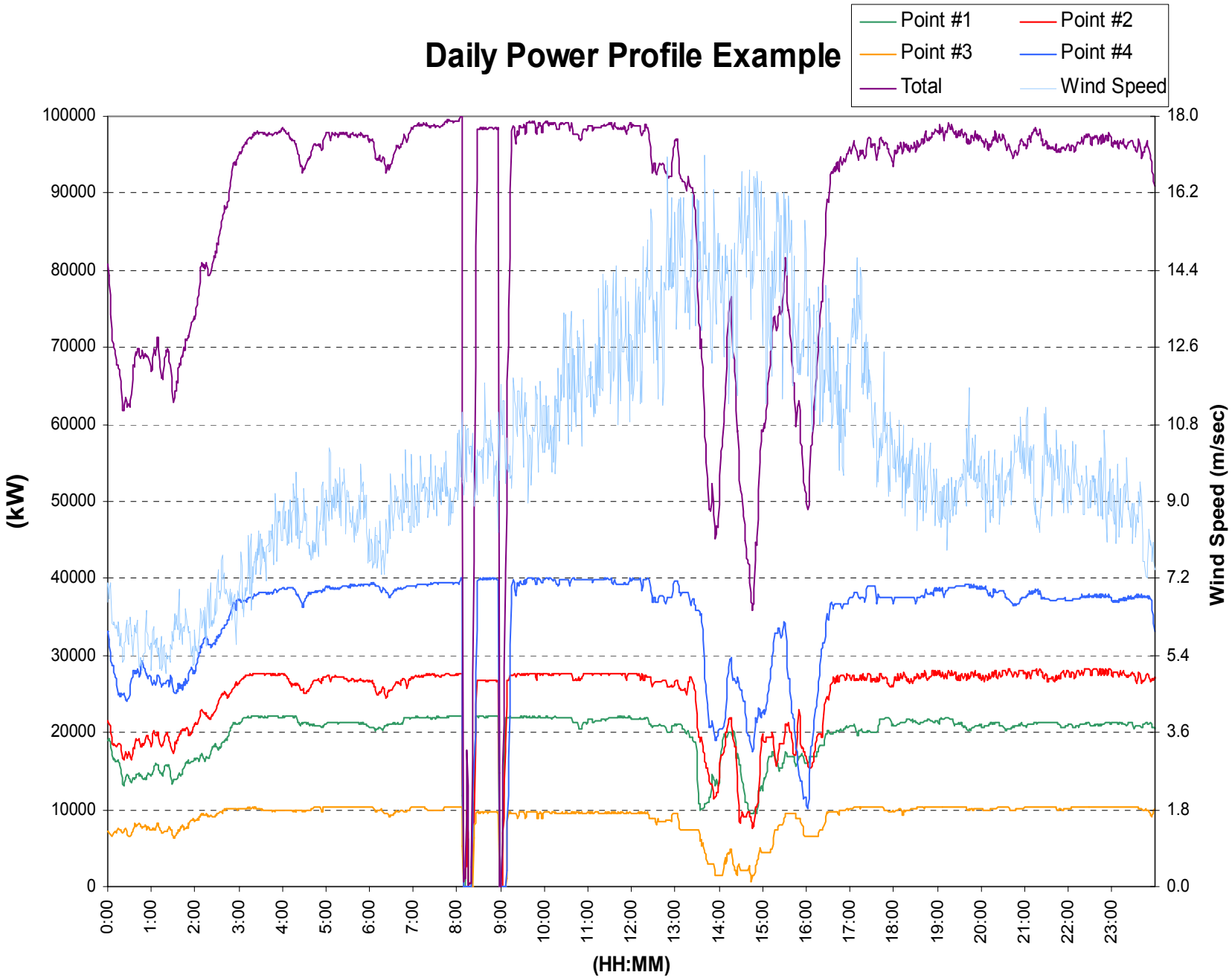
Wind Powering America

•5% of the nation's electricity with wind by 2020

•Double the number of states with > 20 MW of wind capacity to 16 by 2005, and triple to 24 by 2010

Denver Federal Executive Board/DOE Aggregation Efforts

- 10 MW of load aggregated in Denver Area
  - tags considered the preferred alternative
- DOE goals: around 60 MW by green tags being considered
- Power Marketing Association Partnership of WAPA, BPA/BEF, and TVA as contracting mechanism
- Regional, with potential tribal involvement


Daily Power Profile Example
Point #1
Point #2
Point #3
Point #4
Total
Wind Speed
(kW)
Wind Speed (m/sec)
(HH:MM)
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
18.0
16.2
14.4
12.6
10.8
9.0
7.2
5.4
3.6
1.8
0.0
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00

Land Owners, Communities, Economic Development and Local Government Officials

- Messages
  - Wind as a new “crop” for local income and economic development
- Actions
  - formulate facilitating wind-rights and ownership structures (like wind coops)
  - develop zoning and permitting procedures that recognize wind development characteristics and needs
  - develop streamlined project-approval processes

Regulators, Government Officials and other Policy Makers

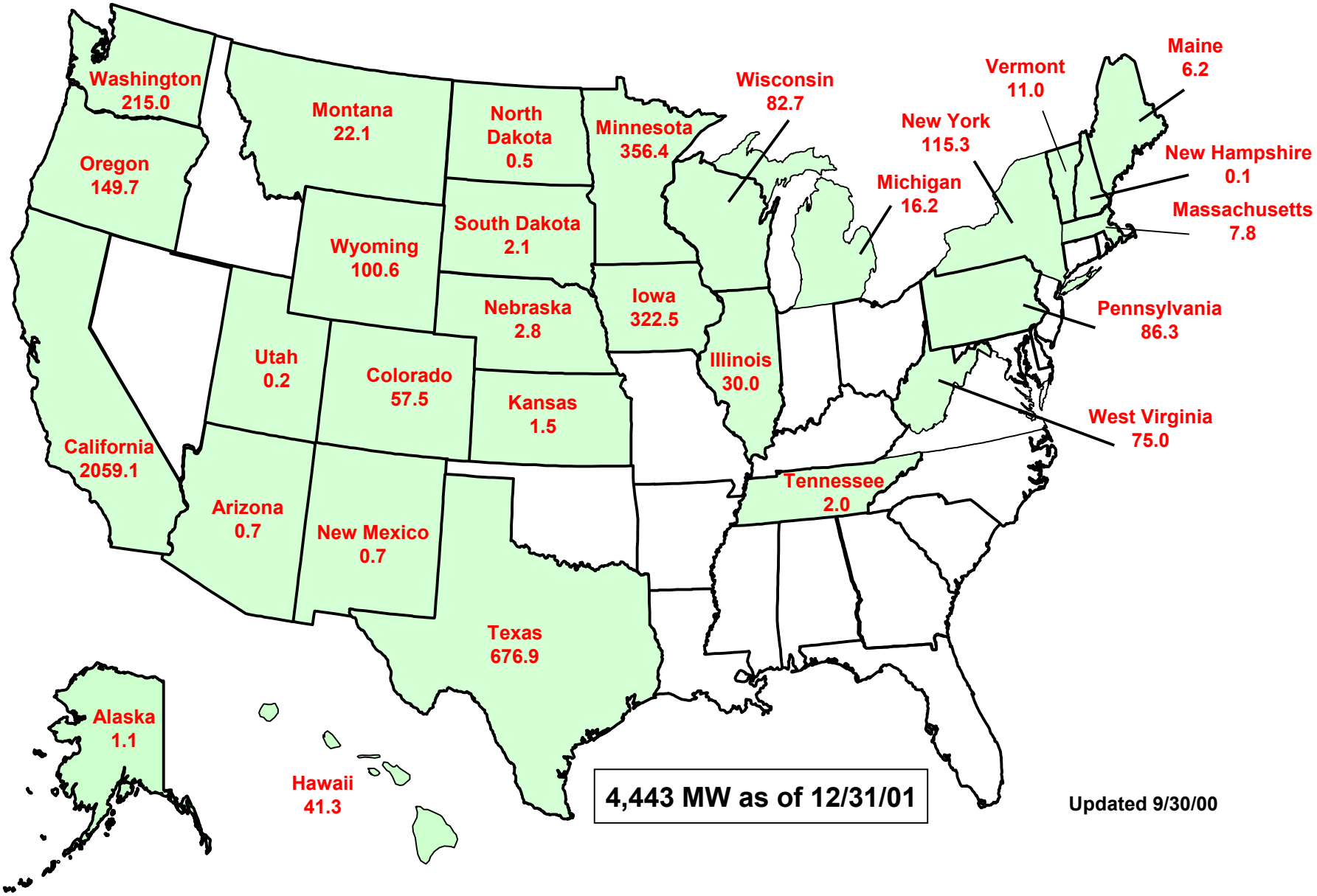
- Messages
  - acceptable economic returns and policies that recognize site/time specific value (not just avoided cost) are needed
  - Interconnection requirements based on reasonable safety and operational considerations need to be standardized
- Actions
  - promote standards development, minimize individual or special studies
  - support publicly funded infrastructure
  - support new valuation methods

Financial Community

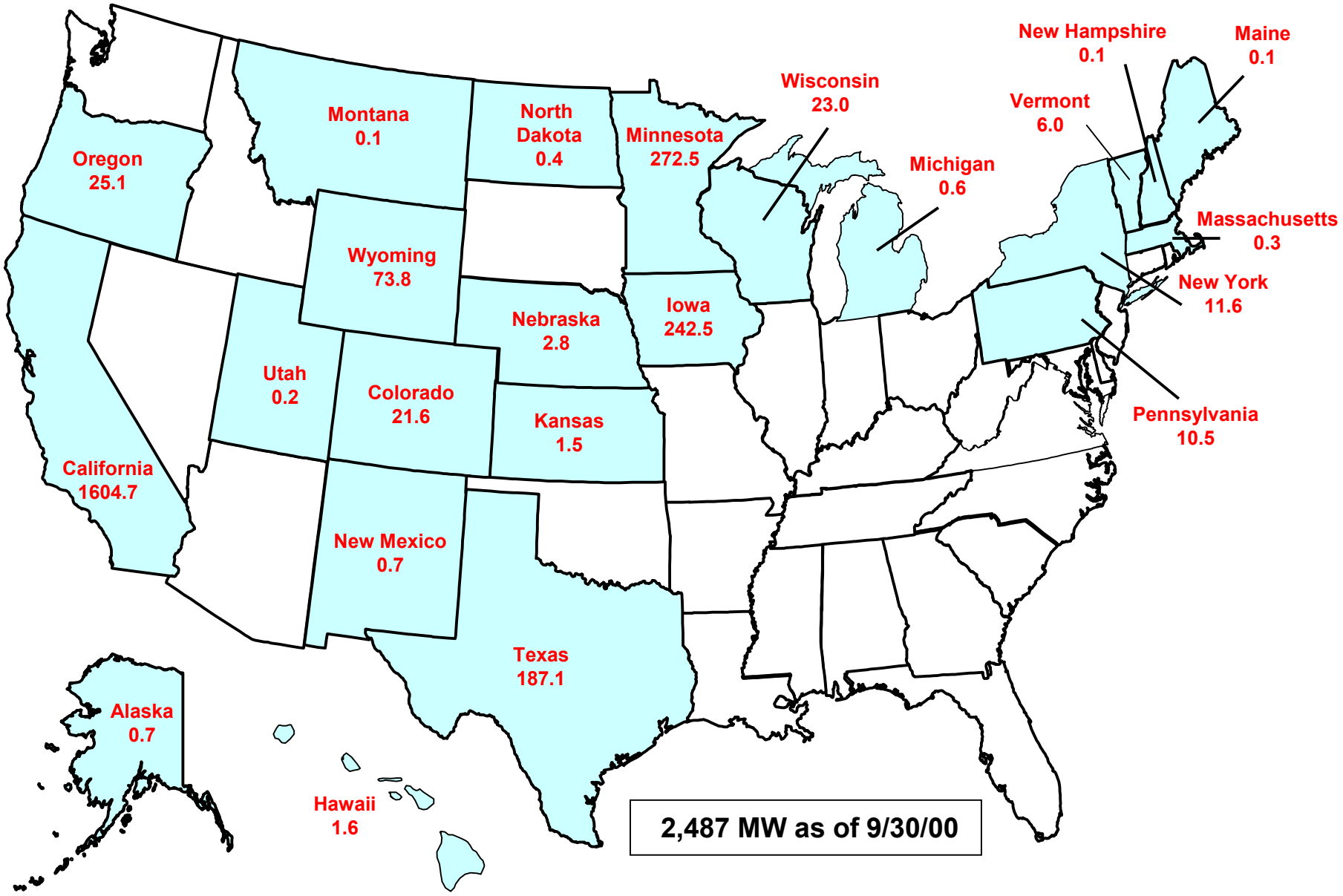
- Messages
  - Financing institutions in Europe provide financing with procedures and terms like standard farm equipment.

- Actions
  - Evaluate risk levels appropriate for distributed project financing.
  - Develop standard financing processes and products to minimize transaction costs.
  - Work to develop power-purchase mechanisms and project ownership structures that reduce risk of project investment.

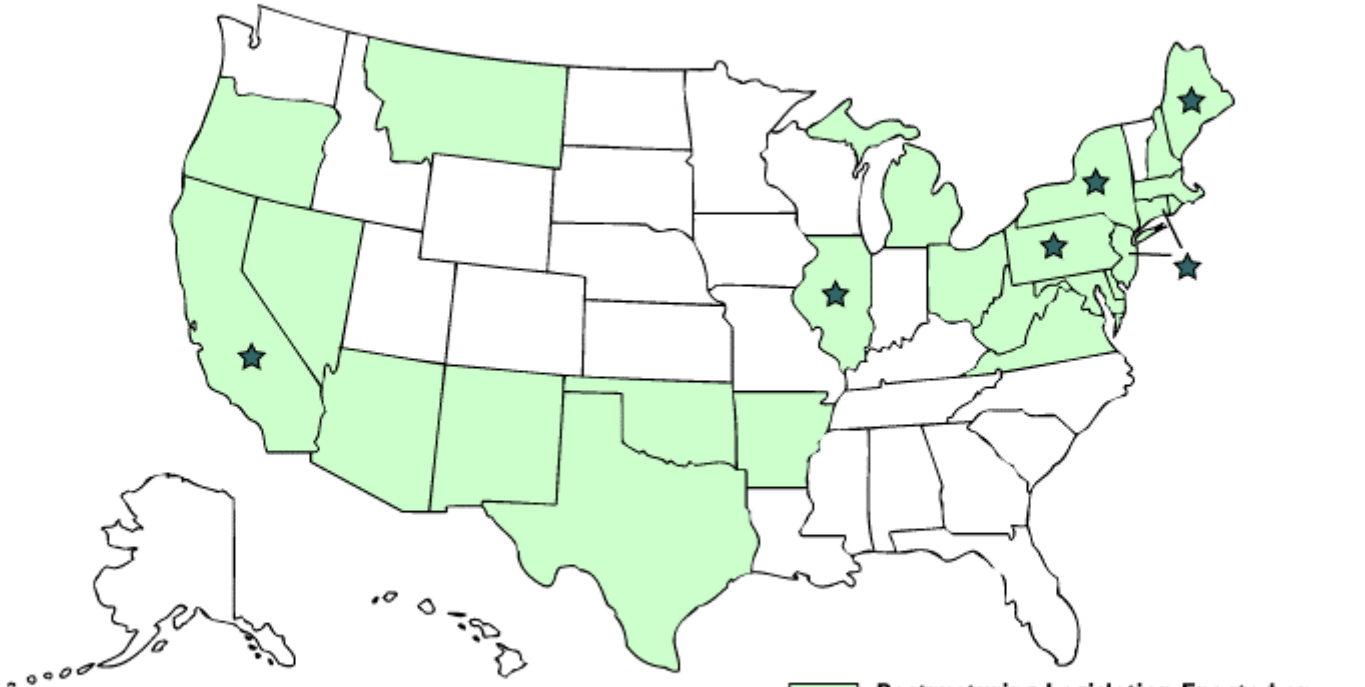
U.S. Wind Power - Expected by end of 2001 (MW)



United States Wind Power Capacity (MW)

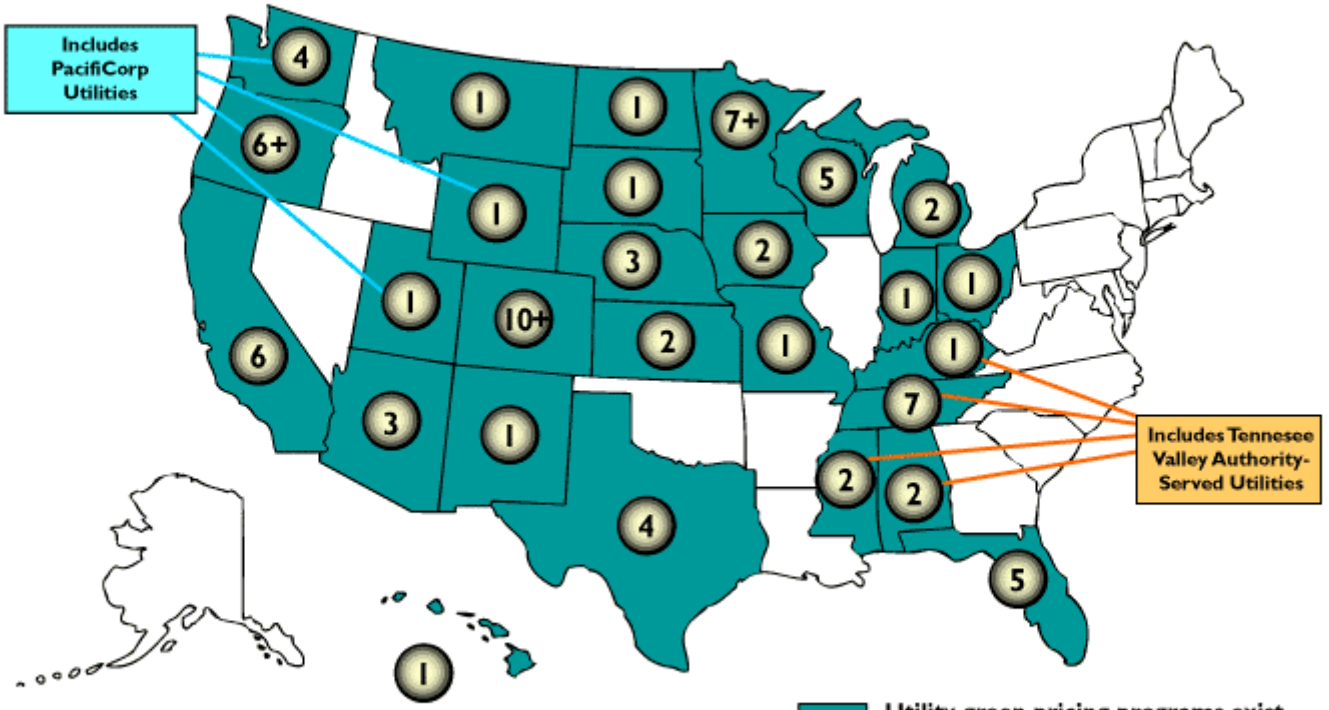


States with Competitive Green Power Offerings



Sources: Energy Information Administration and NREL (June 2000)

Utility Green Pricing Activities



Source: National Renewable Energy Laboratory, September 2000